

Propulsion Across NASA



AIAA NO Section Dinner Meeting

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Outline



- **Introductory Remarks**
- **Propulsion NASA Mission Readiness**
 - Aeronautics Research Mission
 - Science Mission
 - Space Operation Mission
 - Exploration Systems Mission
- **Propulsion Roadmap**
- **Review of Center Capabilities**
- **Current Challenges**

- **This presentation is a compilation of a several presentations**
 - NASA Joint Engineering Management Board and Safety and Mission Assurance Directors' Meeting Brief – Robert Garcia & Mike Meyers (Dec 2008)
 - NASA's Rocket Propulsion Test Management Board
 - NESC Propulsion Technical Discipline Team meeting reviewing respective Center's propulsion activities (July 2010)
 - Plus, general info from NASA's Rocket Propulsion Test program



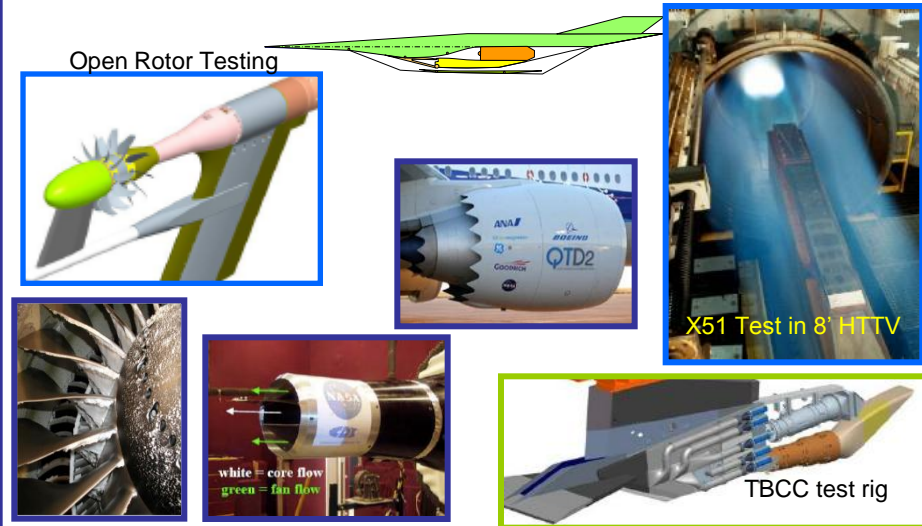
Introductory Remarks



- **Propulsion expertise has recently been in high demand across all of the NASA missions**
 - Constellation in particular placed a large burden and opportunity on NASA's propulsion skills and capability
 - Its replacement program will have equal or greater propulsion systems development needs
- **NASA's missions require a very broad breath of varying propulsion configurations.**
 - Air-breathing (subsonic, supersonic, and hypersonic)
 - Chemical propulsion (liquid, solid, cryogenic, hypergolic)
 - Electric propulsion (battery, solar, nuclear, ...)
 - Within each configuration there are unique subsystems and models of operation
- **While there are overarching common skills, each major branch of the propulsion tree tends to have unique skills and infrastructure needs.**
 - Physics, materials, internal and external environments, time of operations, etc., can lead to unique design, development, and operational capability needs.

Requirements

- **Research into techniques for:**
 - Improved fuel efficiency
 - Noise and emissions reduction
 - Overland travel for supersonic/hypersonic aircraft
 - RBCC/TBCC for launch systems
 - Scramjet for atmospheric travel
- **Collaboration with other government agencies and industry**



Challenges

- **Limited Procurement funding**
- **Loss of competency-supporting WYEs**
 - Developing creative partnerships with industry to enable TRL maturation
- **Support for test infrastructure and operations**

Expertise Resources

Y	Design	↓
G	Analysis	↓
Y	Test	↓

Modeling

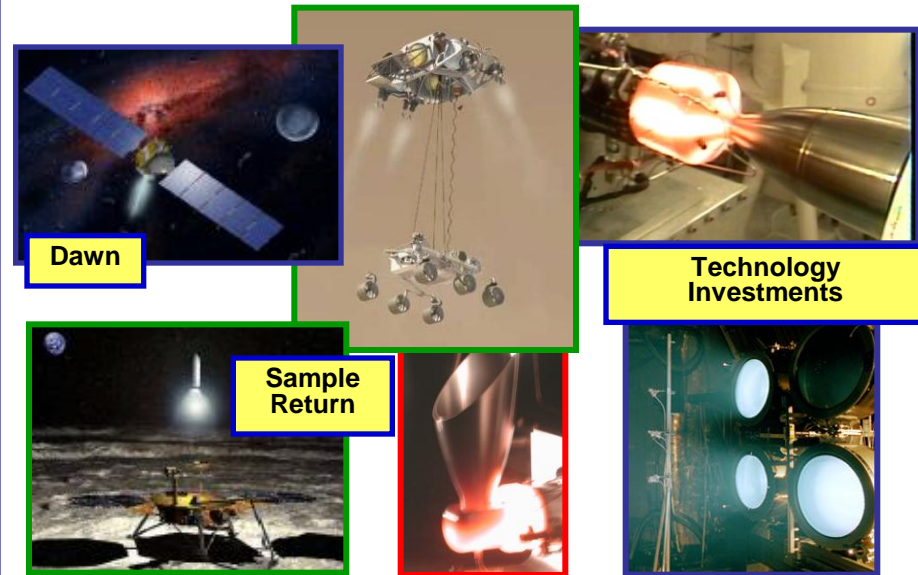
G	System	—
Y	High Fidelity	↓

Facilities

Y	Engineering Evaluation	—
Y	System Test	—

Requirements

- Science mission propulsion generally driven by planetary missions
 - Reduce transit time
 - Increase scientific payload capability
 - Enable sample return missions
 - Mission cost reduction
- Support of missions from pre-Phase A through operations



Challenges

- Identification of long term technology needs
- Declining technology advancement budget
- Transition to flight
- Accurate cost projection
- Competency maintenance for unique NASA mission requirements
- Changing mission priorities

Expertise Resources

Y	Design	—
G	Analysis	—
G	Test	—

Modeling

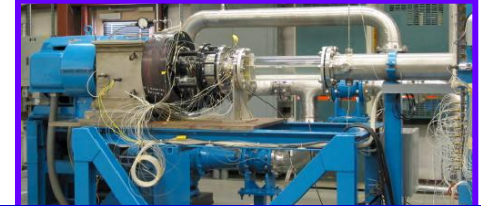
G	System	—
Y	High Fidelity	↓

Facilities

G	Engineering Evaluation	—
G	System Test	—

Requirements

- **Shuttle propulsion operations**
 - Continued safety improvements
 - Hardware acceptance
 - Pre-flight performance predictions
 - Launch operations support
 - Post flight performance assessment
 - Trending analysis



Infrastructure Investments



Challenges

- Graceful/safe end to Shuttle operations and transition to Constellation
- Manufacturing base obsolescence
- Support for infrastructure, skills, capabilities post shuttle

Expertise Resources

G	Design	↓
G	Analysis	—
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Modeling

G	System	—
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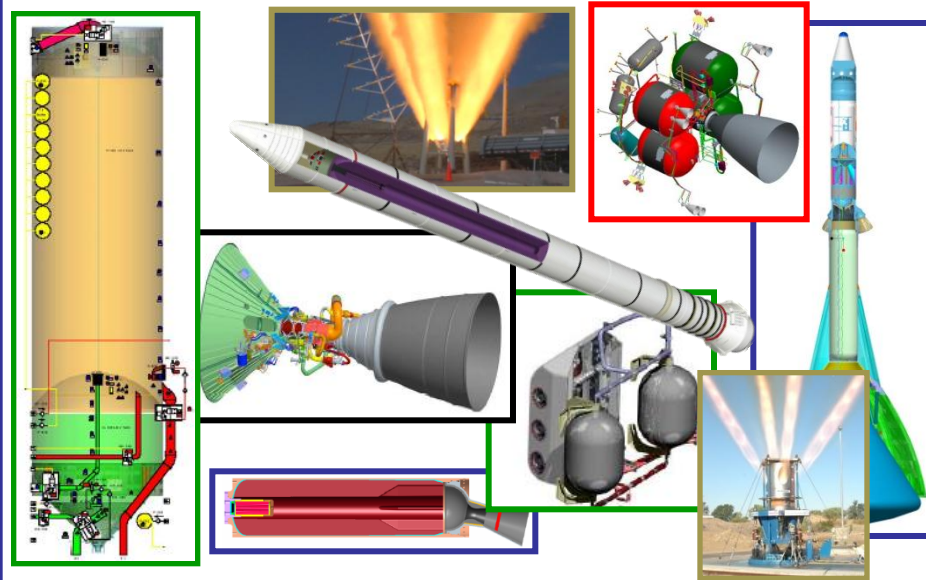
Facilities

G	Engineering Evaluation	—
G	System Test	↓

Exploration System Mission

Requirements

- Independent assessments for Industry led design and design activities
 - Orion, J-2X, RSRMV
 - Requirements definition, development and qualification plans
 - Selected independent analysis and testing
- Design and initial development
 - Upper stage MPS, ullage motors, roll-control, RCS
- Definition and technology development for Ares V and Altair



Challenges

- Rapid “staffing” to catch up with project needs
 - Head-counts addressed, experience a work in progress
- Complex organizational relationships
 - Communication, standards/expectations for “in-house” workforce support
- Lack of standard for propulsion qualification requirements
 - Budget/schedule pressures leading to hardware lean projects.
 - Greater reliance on experience, similarity, analysis

Expertise Resources

Y	Design	↑
G	Analysis	—
G	Test	—

Modeling

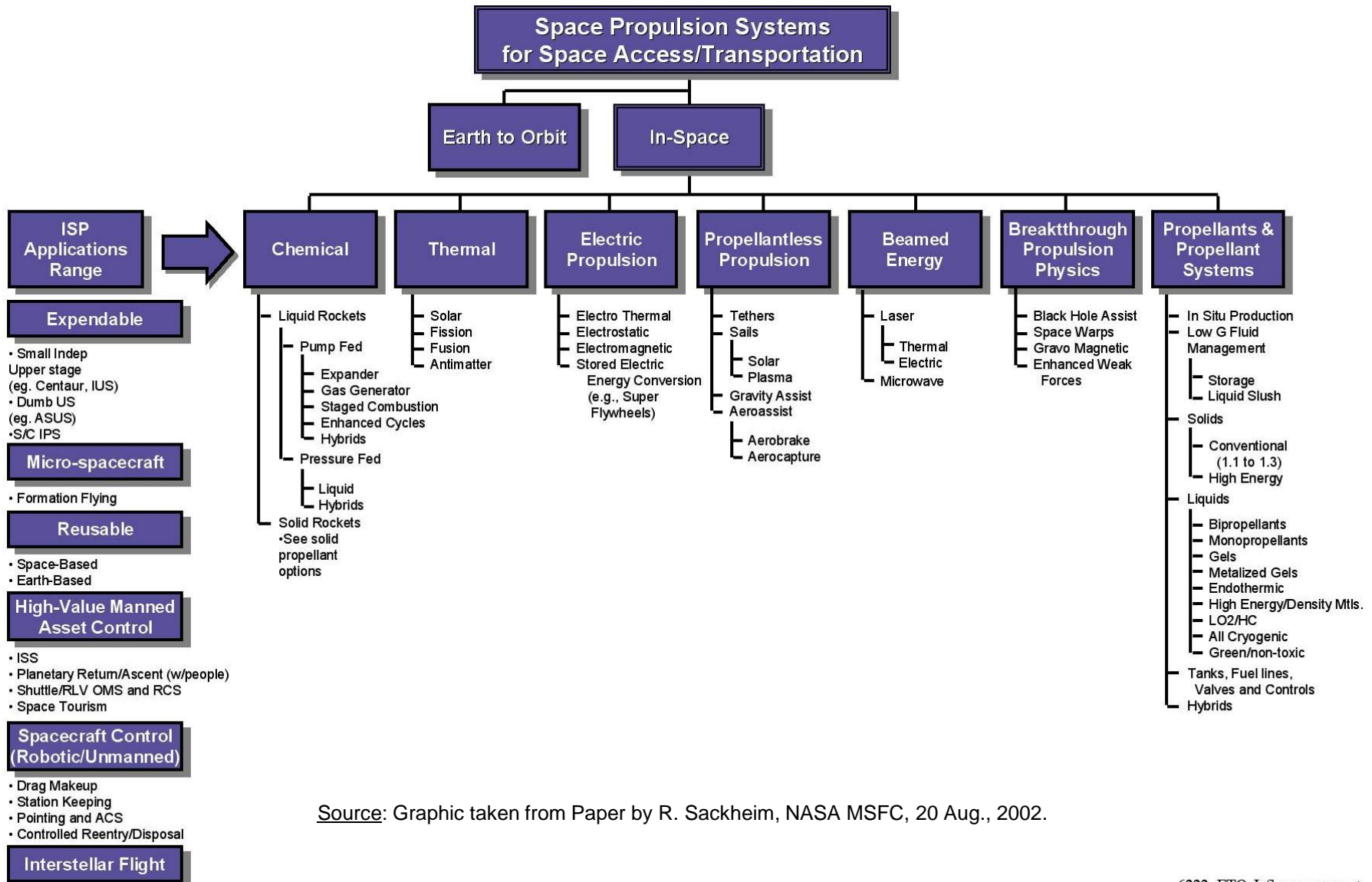
G	System	↑
Y	High Fidelity	—

Facilities

G	Engineering Evaluation	—
Y	System Test	↑



Example of In-Space Propulsion “Tree”





NASA's Rocket Propulsion Test Program

Marshall Space Flight Center:

Primary NASA site for:

- MSFC designed/developed component level test articles
- Technology development test articles with substantial MSFC engineering involvement
- Propulsion component research and technology (low Technology Readiness Level)
- Cryo structural test articles (tanks, ducts, etc.)

Alternate NASA site for:

- Non-hypergolic, ambient testing

White Sands Test Facility:

Primary NASA site for:

- Altitude testing of small/medium test articles up to 15k lb thrust, excluding LOX/LH2
- All hypergolic testing

Plum Brook Station:

Primary NASA site for:

- Altitude testing of medium/large test articles in the 1k to 400k lb thrust range, excluding hypergolics; includes all LOX/LH2 testing

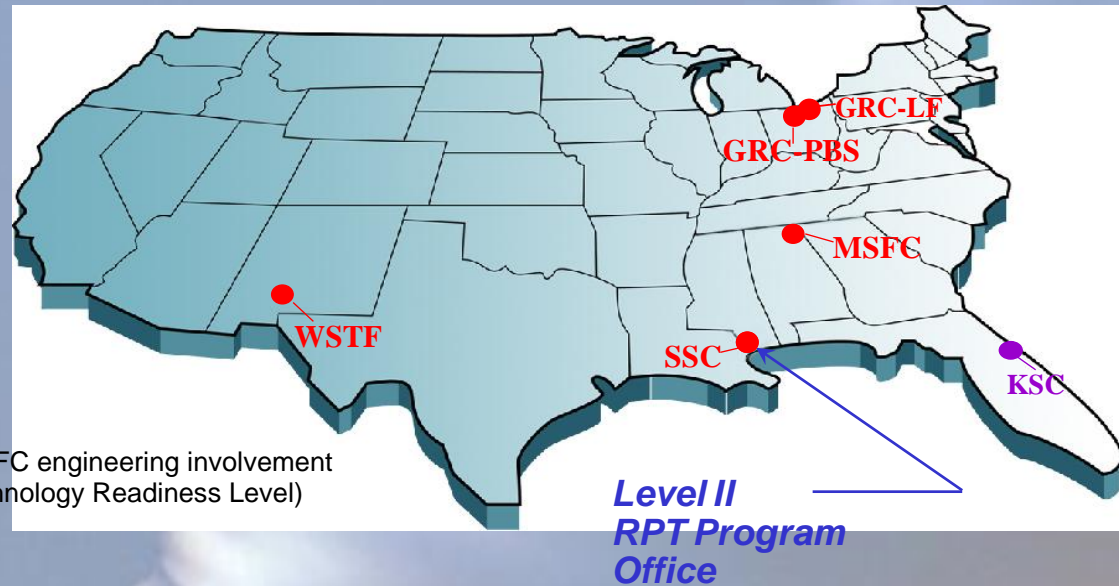
Alternate NASA site for:

- Cryo structural test articles (tanks, ducts, etc.)

Stennis Space Center:

Primary NASA site for:

- Non-hypergolic, ambient/low-altitude testing
- Excludes other centers' baseline test assignments





SSC



Test Complex Visual Perspective

Manage, develop, and operate SSC Rocket Propulsion Test (RPT) capabilities and facilities

- Provide sustaining engineering expertise and operations experience to ensure the safe operation and continued sustainment of one-of-a-kind national test facilities valued at over \$2 billion
- Provide technical oversight of rocket engine propulsion test programs such as the RS68, J-2X & AJ26



SSC Test Stands



FY11: J-2X Powerpack

A-1



FY09: SSME
FY11: J-2X

A-2



FY10: RS68
FY10/11: TBD

B-1

B-2



FY10: Orbital
AJ-26 Engine

E-1



FY09: A3 CSG
FY11: A3 CSG Development

E-2



FY09: A3 SDT
FY10: ALAT

E-3





Rocket Propulsion Test Program

White Sands Test Facility



- Propulsion Test Office
 - Nine Test Stands
 - *Altitude Simulation Systems*
 - *Pyrotechnic Systems Development*
 - *Propellant and Fluids Storage and Distribution Systems*
- Test Support Organizations
 - Precision Cleaning, Component Services, Fabrication, Calibration Labs, Photo/Video/Documentation
 - Chemistry/Metallurgical lab
- Laboratories Office
 - Aerospace Fluids, Materials, and Component Testing
 - Hypervelocity Impact Testing

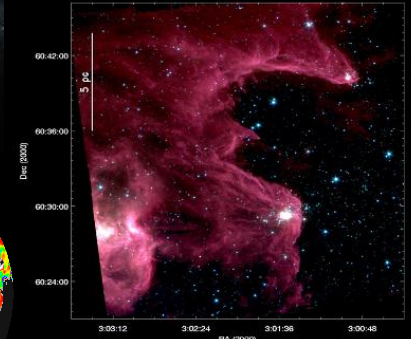
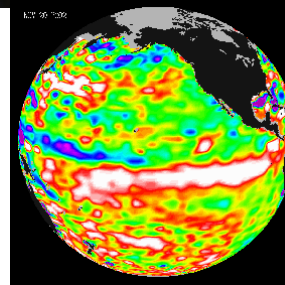
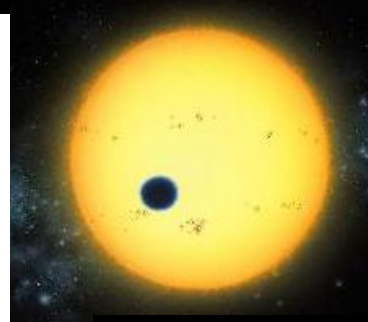
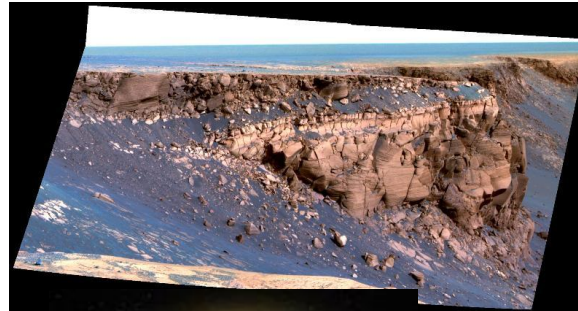


Jet Propulsion Lab



JPL's Mission for NASA is Robotic Space Exploration

- ◆ Mars
- ◆ Solar system
- ◆ Exoplanets
- ◆ Astrophysics
- ◆ Earth Science
- ◆ Interplanetary network

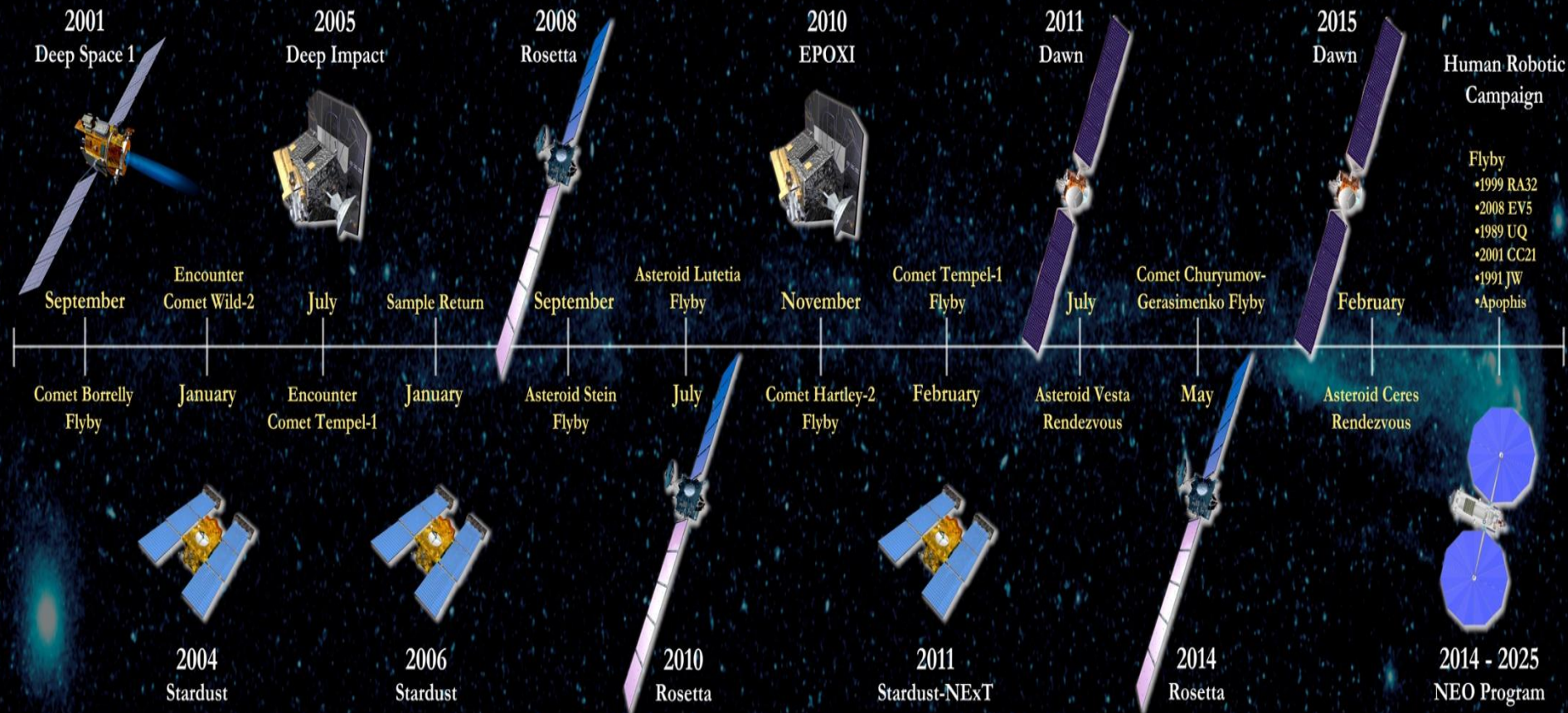




Recent & Planned Asteroid and Comet Mission History



ASTEROID & COMET ENCOUNTERS





Propulsion at JPL



- **Organization**
 - Two propulsion groups at JPL
 - Electric Propulsion and Chemical Propulsion
- **Goals are performance and system improvements for Missions**
 - Technology maturation and implementation
 - System Analysis
 - Test Facilities

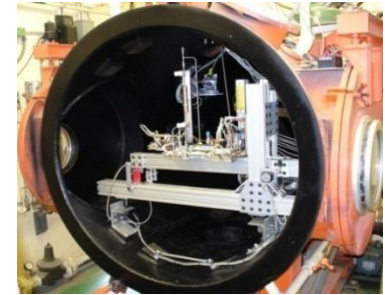




JPL: Low Thrust Chemical Test Facility



❖ *The JPL Chemical Thrust Test Facility has state-of-the-art thrust and impulse measurement systems.*

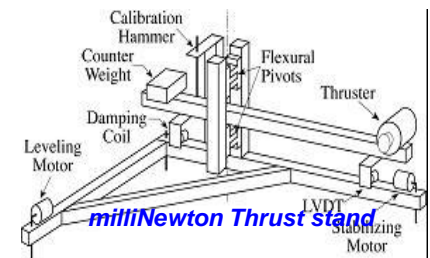


Thrust Stand Infrastructure

- Capability to test a range of thrusters: 22 N – to sub-milliNewton ($< .001\text{N}$)
- Ability to measure individual impulse-bits to < 50 microNewton-seconds.
- Maintain vacuum levels to < 10 millitorr during test.

❖ *Near term plans for testing include:*

- *22 N thrusters using AFM-315e green propellant*
- *R&D Arcjet thrusters for industry*
- *Flight qualification of a 4.5 N hydrazine thruster*



Johnson Space Center

AREAS OF EXPERTISE



PROPULSION

- Cold/warm gas, Earth storables, Cryogenics
- Mono-propellant & Bi-propellant thrusters
- Attitude control systems
- Orbit adjust systems
- Propellant Management & transfer

POWER SYSTEMS

- Fuel Cells
- Primary & secondary batteries
- Chargers
- Electrical power distribution & control

PYROTECHNICS

- Initiators and Detonators
- Linear explosives
- Cartridge Actuated Devices
- Crew escape systems

In-Situ Resource Utilization (ISRU)

- Lunar processing to extract oxygen
- Processing reactors
- Water electrolysis
- Gas/Liquid separation & cleaning

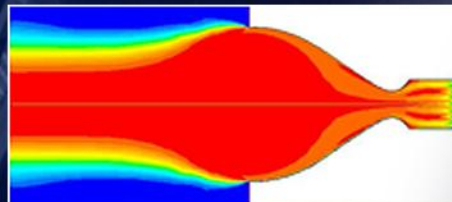
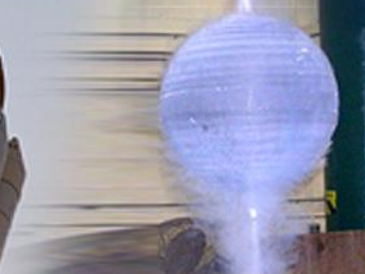
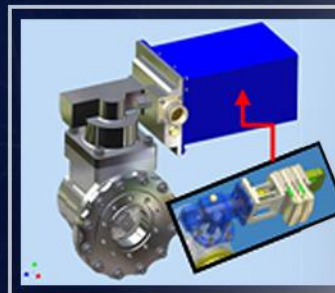


Johnson Space Center

PROPULSION OVERVIEW

JSC's Core Competencies cover the range of skills required for development & operation of Spacecraft Propulsion Systems

- Cold Gas, Earth-Storables, & Cryogenics
- Concept, Mission, & Architecture Trade Studies
- Cryogenic Fluid Management
- System Design & Analysis
- System & Vehicle Integration
- Component Design Expertise
- System Certification & Human Rating
- Flight Operations Support
- Demonstrated Rapid Response for Anomaly Resolution



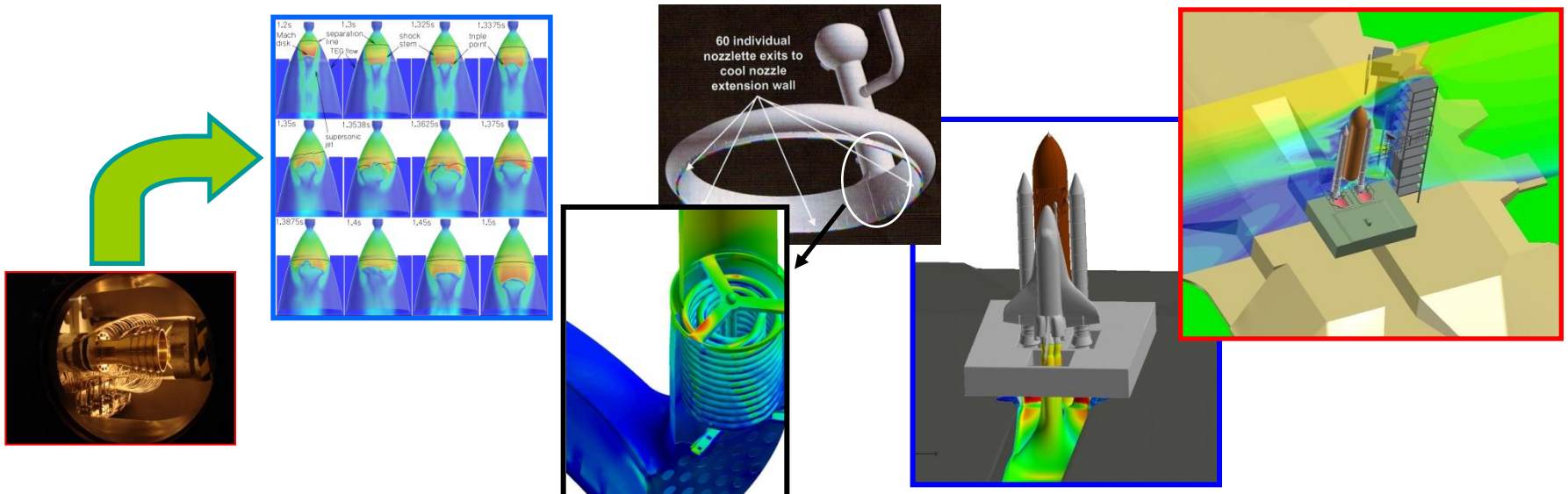








- **Funding for continued improvement in high fidelity simulations and the infrastructure that supports it.**
 - Projects continue to increase reliance on simulation and high fidelity analyses to reduce design risk and performance design verification
 - Propulsion activities are one of the largest users of agency computing resources
 - Time accurate, multi-species, reacting, multi-phase, multi-disciplinary – causes of failure
 - Constellation greatly benefitting from past investments but current support weak
 - The demand is expect to increase sharply over the next 2-7 years
 - Simultaneous Ares 1, Ares V, and Altair propulsion system design, development, and early flight operations

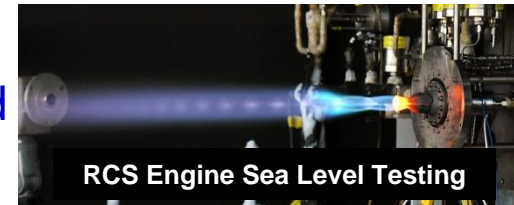




Top Propulsion Challenges (continued)



- **Maintaining NASA mission unique expertise in tight budget situation**
 - Some propulsion expertise may only be needed once or twice a decade to support
- **Development of and insertion of propulsion technology into flight missions**
 - Competitive mission selection process in science and schedules in exploration generally present disincentive for using new propulsion technology
 - Long life demonstration of EP in-space (NEXT)





Summary (from Introductory Remarks)



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Thank You